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(54) Title: METHOD FOR COMPUTERIZED SUPPLY CHAIN PLANNING
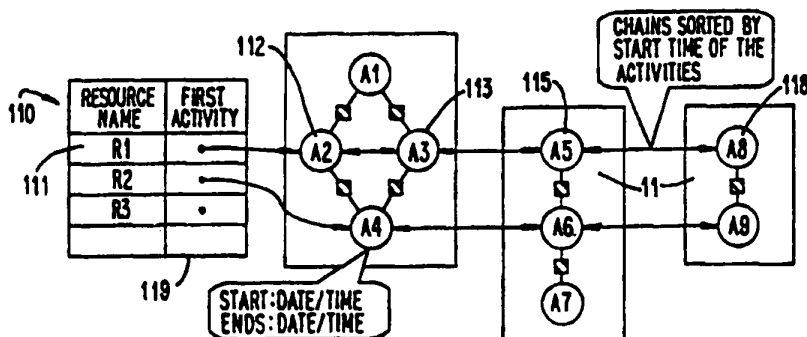
(57) Abstract

A data model for a supply chain is provided whereby individual working steps in a production process are defined as activities, and organized groups of such activities are defined as orders. Activities are allocated to no more than one resource and contain information concerning the start and finish time for the activity, any resource on which the activity is currently scheduled, and a list of alternative resources, if any. Activities are linked to each other via auxillary objects, which contain information concerning the minimum and maximum time between activities. Orders may contain input and/or output interface nodes, representing the materials consumed and produced by the order. Each output interface node representing a quantity of material created from one order is linked via an auxiliary object to respective input interface node or nodes form other orders that are scheduled to receive that material. Order anchors are defined whereby a planning algorithm can easily reference an order by its order number in a database table. Planning algorithm can easily reference an order by its order number in a database table. Planning object anchors allow the planning algorithm to access all the orders for a given material, and resource anchors permit access to all activities scheduled for that resource.

METHOD FOR COMPUTERIZED SUPPLY CHAIN PLANNING

Background of the invention

Supply chain planning ("SCP"), which comprises the
logistical plan of an in-house supply chain, is essential
to the success of many of today's manufacturing firms.
Most manufacturing firms rely on control of their
production plants using computerized supply chain
planning in some form to ensure the timely delivery of
products in response to customer demands. Typically,
supply chain planning is hierarchical in nature,
extending from distribution and production planning
driven by customer orders, to materials and capacity
requirements planning, to shop floor scheduling,
manufacturing execution, and deployment of products.
Supply chain planning ensures the smooth functioning of
different aspects of production, from the ready supply of
components to meet production demands to the timely
transportation of finished goods from the factory to the
customer.

The modern supply chain often encompasses a vast array of
data. The planning applications that create and
dynamically revise plans in the supply chain in response
to changing demands and capacity require rapid access to
data concerning the flow of materials through the supply
chain. The efficient operation of the supply chain
depends upon the ability of the various plans to adjust

to changes, and the way in which the required data is
stored determines the ease with which it can be accessed.

In the conventional relational model, supply chain data
is stored in multiple relational database tables. If a
parameter of a manufacturing order is changed, all of the
aspects of the supply chain affected by such change must
be re-calculated using the relational tables. Before a
planning algorithm can change the date and/or quantity of
a manufacturing order in response to changing capacities,
for example, it must take into account the effect that
the date and/or quantity change will have on other
production and sales orders. Such a calculation is very
complex, and requires that the algorithm have access to
data concerning all the other orders, materials and
resources that would be affected by the change. In the
conventional model that information must be calculated by
tracing through relational database tables. Such
calculations are cumbersome and delay planning functions
unnecessarily.

There is therefore a need for all data relevant to supply
chain planning to be made available by a computerized
method in the most efficient and usable manner possible
so as to reduce drastically the runtime of the planning
functions, thus allowing the required control of
production processes with given computer resources in an
improved manner.

Summary of the invention

To cope with this need the present invention relates to a
data model for storing objects that are relevant for
planning the logistical processes along the entire supply

chain of a company. A data structure is defined whereby
individual working steps in the production process are
defined as activities, and organized groups of such
activities are defined as orders. Activities are
allocated to no more than one resource, if any, and
contain information concerning the start and finish time
for the activity, any resource on which the activity is
currently scheduled, and a list of alternative resources,
if any. Activities representing a time calculation only
are not required to correspond to a resource. Activities
are linked to each other via auxiliary objects, which
contain information concerning the minimum and maximum
time between activities. Orders may contain input and/or
output interface nodes, representing the materials
consumed and produced by activities within the order. An
output interface node representing a quantity of material
created from one order is linked via an auxiliary object
to respective input interface node or nodes from other
orders that require that material. Order anchors are
defined whereby a planning algorithm can easily reference
an order in the data structure by its order number in a
database table. Planning object anchors allow the
planning algorithm to access all the orders for a given
material, and resource anchors permit access to all
activities scheduled for that resource.

More specifically the invention provides a method for
computerized supply chain planning, comprising a data
model, said data model comprising at least one order
which comprises at least one activity, wherein each of
said at least one activity represents a working step that
is indivisible from a production planning perspective;
each of said at least one activity is linked to a
reference to all immediately subsequent activities of
said order; and each of said at least one activity is

linked to a reference to all immediately preceding
activities of said order.

Preferred embodiments are defined in the subclaims.

In summary, the following features and achievements of
supply chain planning using the instant data model may be
noted:

The invention allows to store manufacturing process data
so as to provide planning algorithms and applications
programs with the most efficient access possible to the
data that they require.

The data are stored in a logical manner that reflects the
progress of materials and orders along the supply chain.

Discrete data elements representing individual working
steps in the production process are defined, and the
relationships between said elements are stored.

Specific information about each working step is linked
with those data elements, including the start time,
finish time, and the resources upon which the working
step is performed or alternatively may be performed.

Groups of working steps in the manufacturing process are
organized as objects that can be accessed by planning
algorithms, and the relationships between said groups of
working steps are stored.

A planning algorithm has efficient access to any
organized group of working steps in the production
process by providing a database table whereby each of the

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groups of working steps is referenced to its location in the data structure.

A planning algorithm also has efficient access to the working step performed by a given resource at a specific time, by providing a database table whereby the dates and times of all working steps performed by each resource are referenced to that resource.

A planning algorithm furthermore has efficient access to organized groups of working steps involved in creating or consuming a specific material, by providing a database table whereby information identifying the material is referenced to the input or output of each such organized group of working steps.

Brief Description of the Drawings

Figure 1 is a representation of the relationship
        between an order and its activities.

Figure 2 is a representation of the fusing of
        activities to make operations.

Figure 3 is a representation of the input and output
        interface nodes of an order.

Figure 4 is a representation of input activities,
        output activities, and activities with no input
        or output.

Figure 5 is a representation of how temporal
        constraints between activities are modeled.

Figure 6 is a representation of how temporal
        constraints between orders are modeled.

Figure 7 is a representation of a simple order network
        with pegging.

Figure 8 is a representation of how pegging between
        orders is modeled.

Figure 9 is a representation of an order anchor and an
        operation anchor.

Figure 10 is a representation of a planning object
        anchor.

Figure 11 is a representation of a resource anchor.

Detailed Description of the Drawings

As shown in Figure 1, an order 10 represents an
organizational unit that may group together several
activities 11. Each order points to the first activity
and the last activity of its activity network. Thus,
order 10 points to activity 12 and activity 13. Each
activity 11 contains a reference 14 to its order. As
depicted in Figure 2, related activities such as a chain
of activities 11a, 11b, and 11c that must be executed in
order may be grouped together into an "operation" 20 to
avoid having to map each activity individually on a
planning table.

An order, such as order 10, may have one or more input
interface nodes 30 and/or one or more output interface
nodes 31, as shown in Figure 3. Each input interface node

30 represents one material. An input interface node also
has attributes containing information as to the quantity
of the material required, the time requirement of the
material, and the shortage of that material, which is
derived from the difference between the quantity of
material required and the quantity that it delivered by
other orders or stock. Each output interface node 31 has
similar attributes, such as type of material created, the
quantity of the material, the time availability of the
material, and the surplus of that material, which is
derived from the quantity of material produced that is
not yet delivered to other orders. Each input interface
node 30 may refer to the activity 12, if any, in which
the material that it represents is consumed, and each
output interface node 31 points to the activity 13, if
any, in which the material that it represents is created.
If an activity 12 consumes a material, all input
materials of this activity can be traced via arrow marked
with dashes and dots 32a that points from activity 12 to
input interface node 30. If input activity 12 consumes
more than one material, arrow 32b joins input interface
node 30a to the next input interface node 30b, which
links on the same input activity 12. The chain of input
interface nodes 30, which can have an infinite length,
allows to ascertain which materials are required for the
order in question, which means that the bill of materials
for the output materials can be determined. Similarly,
the output materials of an activity can be traced via
arrow marked with dashes and dots 34 joining the activity
with the first output interface node 31 of the activity
13. If there are several output materials, then an arrow
33 joins output interface node 31a to the next output
interface node 31b, which represents the second material
created. Like the input interface nodes 30, this chain
can have an infinite length.

Figure 4 illustrates order 10 having activities 41 with
no input or output materials, and also activities such as
assembly process 42 that both consume and create
materials. Stock or a purchase order of a material is
modeled by an order with one output interface node 31 and
with no input interface nodes or activities. If the
capacity of the vendor is to be taken into account in
modeling a purchase order, however, the purchase order
must contain at least one activity representing the
available capacity of the vendor (as accurately as
possible). A plurality of purchase orders may be grouped
into a "schedule line", which is modeled as a purchase
order with several output interface nodes, each with a
different delivery time. Customer requirements mirror
purchase orders: each order has one input interface node
30, but no output interface nodes or activities. Orders
that consume materials such as customer orders are
modeled as "issuing elements", while orders that create
materials are modeled as "receiving elements", allowing
both types of orders to be modeled as objects similar to
other components in the SCP model, thereby saving the
need to create additional algorithms to operate on the
model. An order without input or output interface nodes
may exist, for example, as an order representing a test
or maintenance on a resource.

Links may also be created between successive activities,
said links containing references not only to successor
activities, but also to the minimum and maximum time
between activities. These temporal constraints can exist
both between activities in the same order (intra-order
constraints), and between activities belonging to dif-
ferent orders (cross-order constraints).

Figure 5 illustrates intra-order temporal constraints
between activities. As shown in Figure 5a, activity 11d
has three successor activities 11e, 11f, and 11g. Edges
50, 51 and 52 representing the temporal constraints have
attributes, which are the minimum and maximum time
interval between activities, and the type of temporal
constraint, such as start-start, start-finish,
finishfinish, or finish-start. References to successive
activities are modeled by following the full and dashed
straight arrows. In Figure 5b, starting from activity
11d, first follow the arrow "succ_edge" 51 to reach the
first successor activity from the small square 53 along
the edge "succ_act" 52. This process is repeated from the
first small square in order to reach all other successor
activities successively. The small squares 53 are symbols
of auxiliary objects, which store the references to the
successor activities, the next auxiliary object, and all
the attributes of the temporal constraint between
activities. The same technique can be used to model
predecessor constraints, for example by following the
curved arrows "pred_edge" 54 and "pred_act" 55 to find
the predecessors of activity 11h.

Cross-order temporal constraints are illustrated in
Figure 6. A first order 61 and a second order 62 each
contain three activities 11. There is a cross-order
temporal constraint between activity 11j of first order
61 and activity 11n of second order 62. This constraint
is mapped in the same way as described above for an
intra-order temporal constraint, showing that activity
11j has successor activities 11k and 11o, and that
activity 11o has predecessor activities 11j and 11n.

Similarly, "pegging" links two orders wherein one of the
orders supplies a material consumed by the other order.
Pegging tracks the type and quantity of material supplied
by one order (the "subordinate order") to another order
(the "superior order"). Pegging allows to ascertain the
superior and subordinate orders for any given order at
any given time. If the dates of an order are rescheduled,
pegging allows all other orders influenced by this change
to be updated.

Figure 7 illustrates an example of pegging between
orders, consisting of five orders 71, 72, 73, 74 and 75
that produce or consume materials M1, M2 and/or M3. As
shown, for example, one piece each of M2 and M3 is
required to produce M1. Next to each input interface node
30 respective attributes are shown which are the required
quantity and the requirements date. Next to each output
interface 31 node the shown attributes are the quantity
created and the availability date. For example, order 71
produces 100 M2, which is sufficient to satisfy the
demands of orders 72 and 73 producing M1. The demand of
order 73 is satisfied by orders 71 and 75.

As shown in Figure 8, relationships between orders are
mapped in the same manner as are temporal constraints
between activities. The orders which M2 order 71 supplies
can be found by starting from output interface node 31 of
the M2 order 71 and alternately following the full
straight arrows ("succ_edge") 51 and the dashed straight
arrows ("succ_act") 52. Similarly, the orders that supply
M1 order 73 can be found by starting from the input
interface nodes 30 of M1 order 73, and alternately
following the full curved arrows ("pred_edge") 54 and
dashed arrows ("pred_output") 55 to output interface node
31 of the supplying orders 71 and 75.

While pegging can link a large network of orders, not all
orders have relationships to each other. Accordingly, the
SCP network is usually a collection of disjunctive sub-
networks, making it difficult to scan the whole network
to locate a specific order. Accordingly, an "order
anchor" 90 as shown in Figure 9 can provide direct access
to an order 10 or group of orders in the SCP network via
an "order number" 91. This information is preferably
stored in a RAM-buffered relational database table with a
primary index for the order number and a secondary index
for the reference to the order in the network, or object
identity ("OID") 92. Similarly, an "operation anchor" 93
can provide direct access to an operation 20, or fused
activities, within an order 10. The key 97 of the
operation anchor 93 is the OID 92 for order 10, which is
referenced to the predetermined operation number 94, an
operation number within that order 95, and the first
activity 96 of the respective operation 20. So for an
application program to access a certain operation 20 of
an order 10, it must first use the order anchor 90 to
determine the OID 92 for the order, then use the
operation anchor 93 to find the first activity 96 of the
operation 20 that it is seeking.

Planning object anchors 100, illustrated in Figure 10,
enable an application program to determine efficiently
all the orders 10 for a given material. Each material is
identified in a relational database table according to
its material number 101, plant 102, storage location 103,
and batch 104, collectively designated as a "planning
object". Planning object anchors in table 109 reference
to first input interface node 105 for material M4, and
first output interface node 106 for material M1. All
input interface nodes 30 and output interface nodes 31 of

each material are kept in doubly concatenated lists which
are sorted according to requirements and availability
dates, as shown in Figure 10. Thus, it is possible to
select all receiving and issuing elements for each
material or "planning object", which can be important for
materials requirements planning.

Since each activity preferably corresponds to one spe-
cific resource, a resource anchor is provided to enable
an application program to determine all activities for a
specific resource. Figure 11 depicts a resource anchor
110 modeled as a relational database table 119 that
references each resource number 111 to the corresponding
first activity A2 scheduled on that resource. The first
activity A2 112 is then linked to the next activity A3
113 scheduled on the same resource, which is in turn
linked to subsequent activities A5 115 and A8 118 in
chronological order according to schedule time. This
facilitates the scheduling of new activities on
particular resources. For example, in order to schedule a
new activity on a resource, an application program must
first check the activity immediately before and the
activity immediately after the proposed time for the new
activity to determine whether there is sufficient time to
perform the new activity on that resource. Since resource
anchor 110 stores all activities of a particular resource
chronologically referenced to that resource, this
information is easily and rapidly accessible to an
applications program.

Claims

1. Method for computerized supply chain planning,
    comprising a data model, said data model comprising
    at least one order which comprises at least one
    activity, wherein:

    each of said at least one activity represents a
    working step that is indivisible from a production
    planning perspective;

    each of said at least one activity is linked to a
    reference to all immediately subsequent activities of
    said order; and

    each of said at least one activity is linked to a
    reference to all immediately preceding activities of
    said order.

2. The method of claim 1, wherein said at least one
    order comprises at least one of

    one or more input interface nodes, wherein each input
    interface node represents a material consumed by said
    at least one order, each input interface node being
    linked to all activities that consume said material;
    and

    one or more output interface nodes, wherein each
    output interface node represents a material created
    by said at least one order, each output interface
    node being linked to all activities that create said
    material.

3. The method of claim 1, wherein said data model
    comprises a plurality of orders and each output
    interface node of a first order is linked to a
    reference to a respective input interface node of
    each subsequent order scheduled to consume the
    material associated with said output interface node
    of said first order.

4. The method of any one of claims 1 to 3, wherein said
    data model comprises an order in which said reference
    to all immediately preceding activities and said
    reference to all immediately subsequent activities
    each have at least two attributes, said at least two
    attributes including (i) the minimum and maximum time
    interval between activities and (ii) the type of
    temporal constraint.

5. The method of any one of claims 1 to 4, wherein said
    data model comprises an order in which each of said
    at least one activity has at least four attributes,
    said at least four attributes including (i) a start
    and (ii) finish time, a (iii) reference to the
    resource on which the activity is currently
    scheduled, and (iv) a reference to a list of one or
    more alternative resources.

6. The method of any one of claims 2 to 5, wherein said
    data model comprises an order in which each input
    interface node contains information regarding a
    required material, required quantity, the time at
    which said required material is required, and any
    shortage of said required material, said shortage
    defined as the difference between the required
    quantity and the quantity of said required material
   that is delivered by other orders or stock, and

wherein each output interface node contains
information regarding a created material, created
quantity, the time at which said created material is
created, and any surplus of said created material,
said surplus defined as the difference between the
created quantity and the quantity of said created
material that is not yet delivered to other orders.

7.   The method of any one of claims 1 to 6, wherein said
      data model comprises a plurality of orders which have
      pre-assigned order numbers, said data model further
      comprising a database table having an entry for each
      pre-assigned order number matched to its object
      identity, which is a reference to the respective
      order.

8.   The method of any one of claims 1 to 7, wherein said
      data model comprises an order in which a plurality of
      said activities within said order constitutes an
      operation, and wherein each operation has a pre-
      assigned operation number, said data model further
      comprising a database table having an entry for each
      object identity and pre-assigned operation number
      matched to the earliest activity of the respective
      operation.

9.   The method of any one of claims 2 to 8, wherein each
      material has a pre-assigned material number, said
      data model further comprising a database table having
      an entry for each pre-assigned material number
      matched to a reference to at least one input
      interface node at which the respective material is
      consumed, and an entry for each pre-assigned material
   number matched to a reference to at least one output

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interface node at which the respective material is
created.

10. The method of claim 9, wherein said database table
    further comprises identifying information for each
    material including at least one of plant, storage
    location, and batch.

11. The method of any one of claims 2 to 10, wherein each
    resource has a pre-assigned resource number, said
    data model further comprising a database table having
    an entry for each pre-assigned resource number
    matched to a chronological sequence of activities
    scheduled on the respective resource.

FIG_1

FIG_2

FIG_3

FIG_4
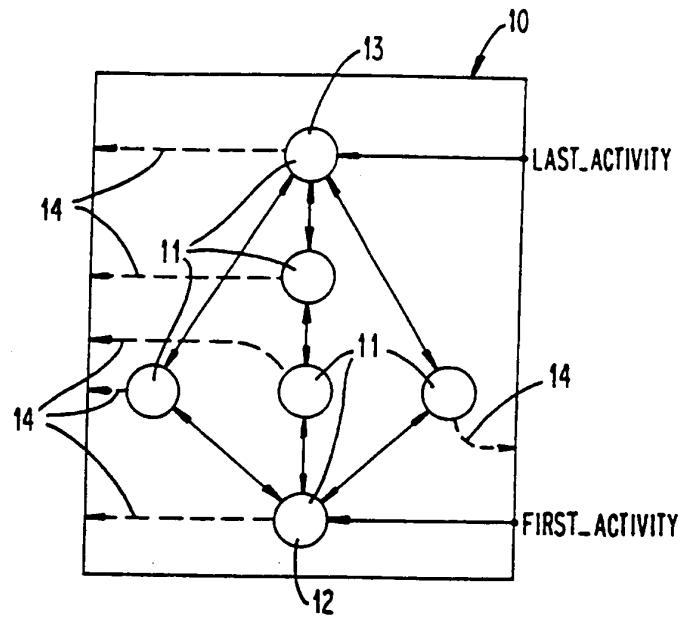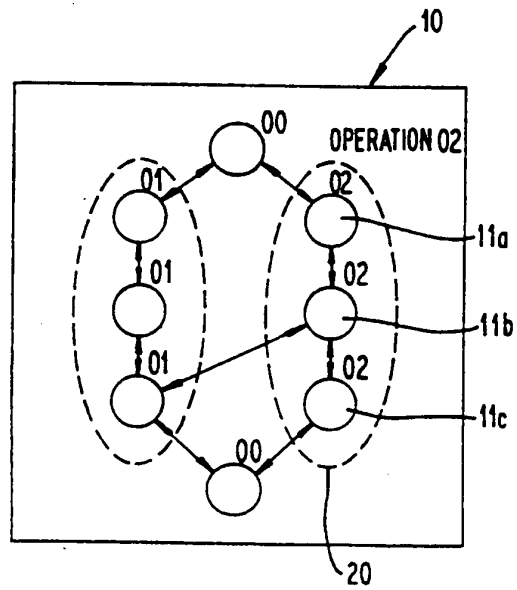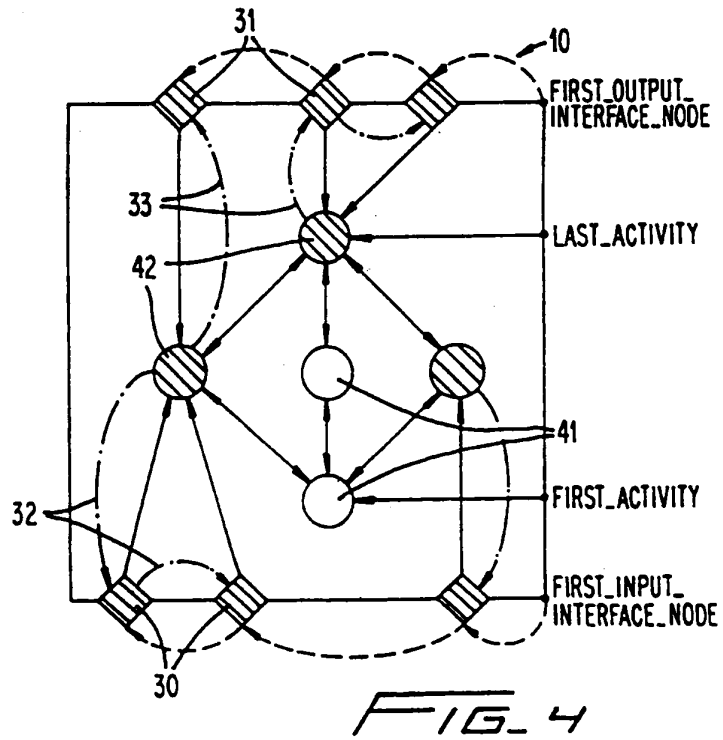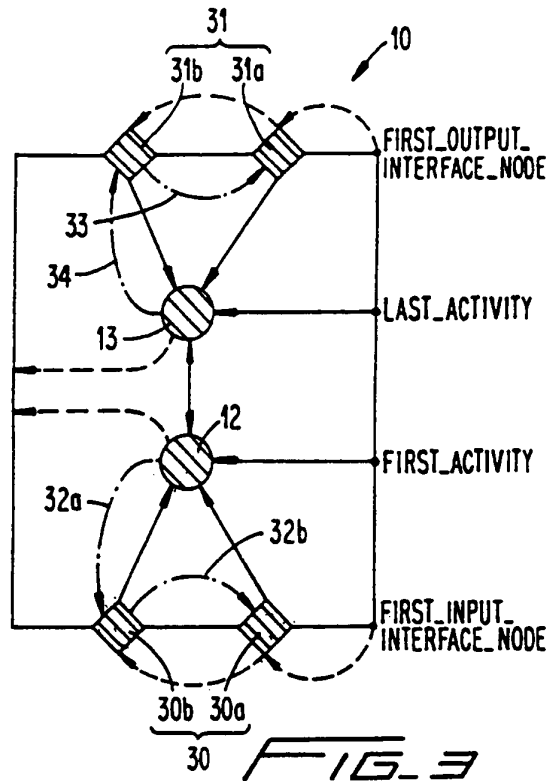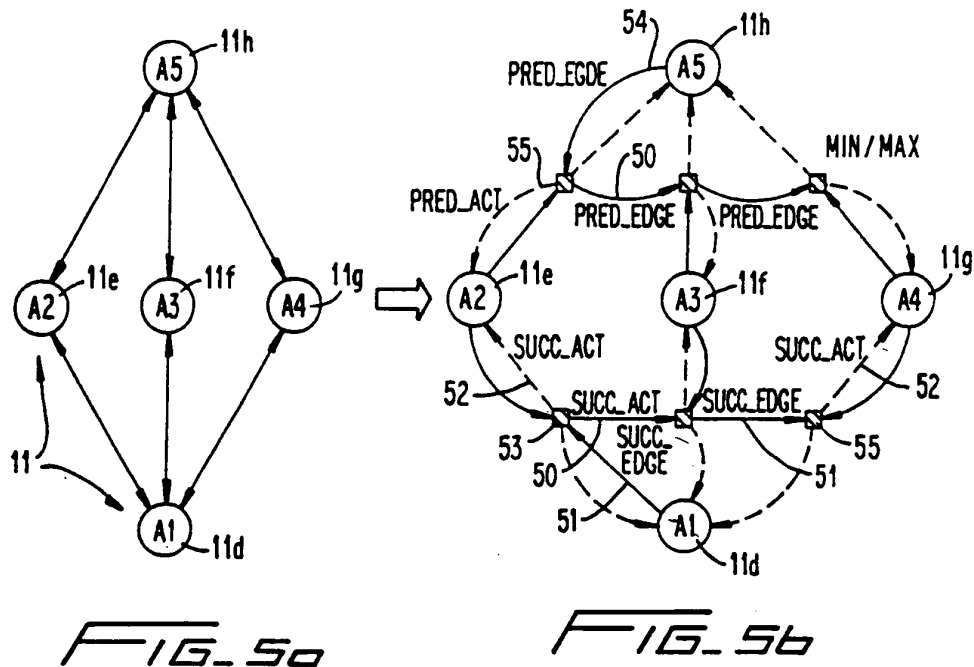
FIG. 5a   FIG. 5b

FIG. 6

FIG_7

FIG_8

ORDER NO.	ORDER-ID	DESCRIPTIVE ATTRIBUTES
4711	0x1234	
4712	0x3627	

ORDER-ID	OPERATION NO.	SCP OPERATION NO.	FIRST ACTIVITY	DESCRITIVE ATTRIBUTES
0x3627	0040	01		
0x3527	0050	02		

FIG_9

MATERIAL	PLANT	STORAGE LOCATION	BATCH	FIRST INPUT INTERFACE	FIRST OUTPUT INTERFACE
M1	0001				
M1	0001	0089			
M4	0001				
M4	0001	0123			
M5	0002	0010			
M5	0002	0010	A		
M6	0002	0010			
-					

PLANNING OBJECT
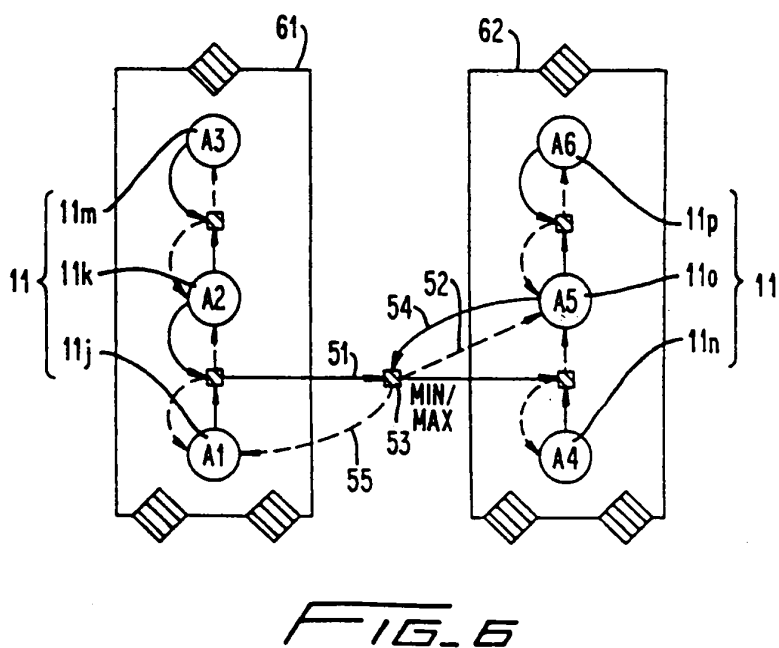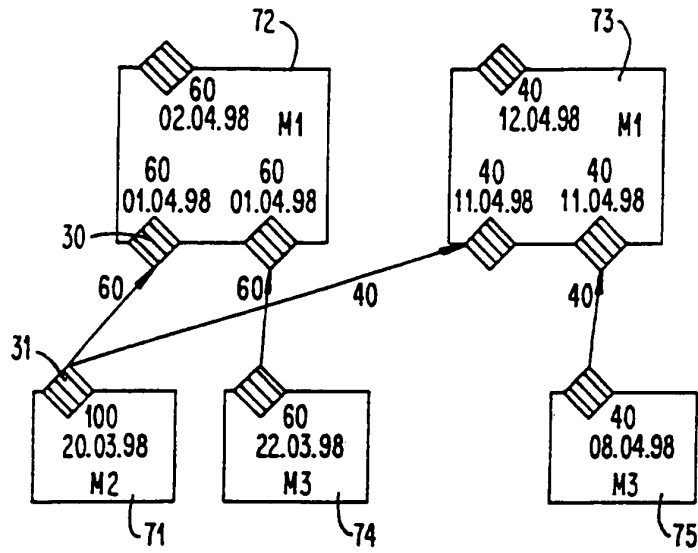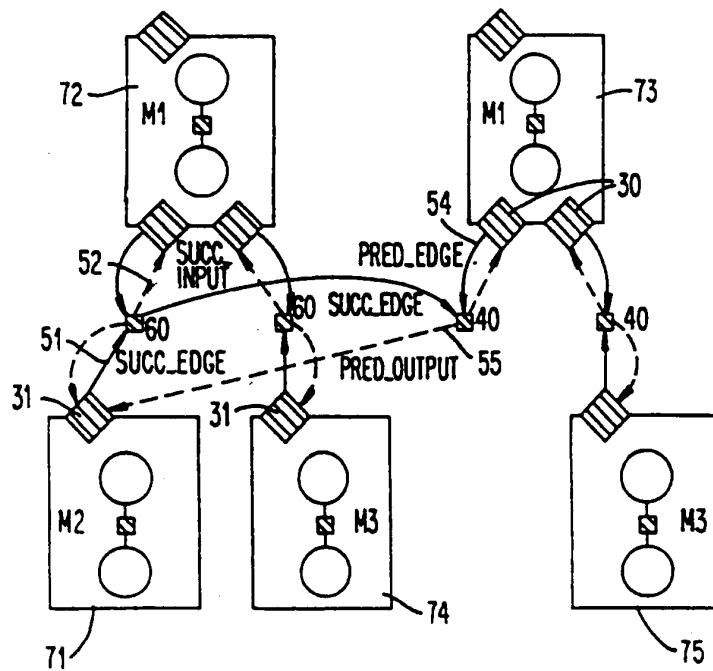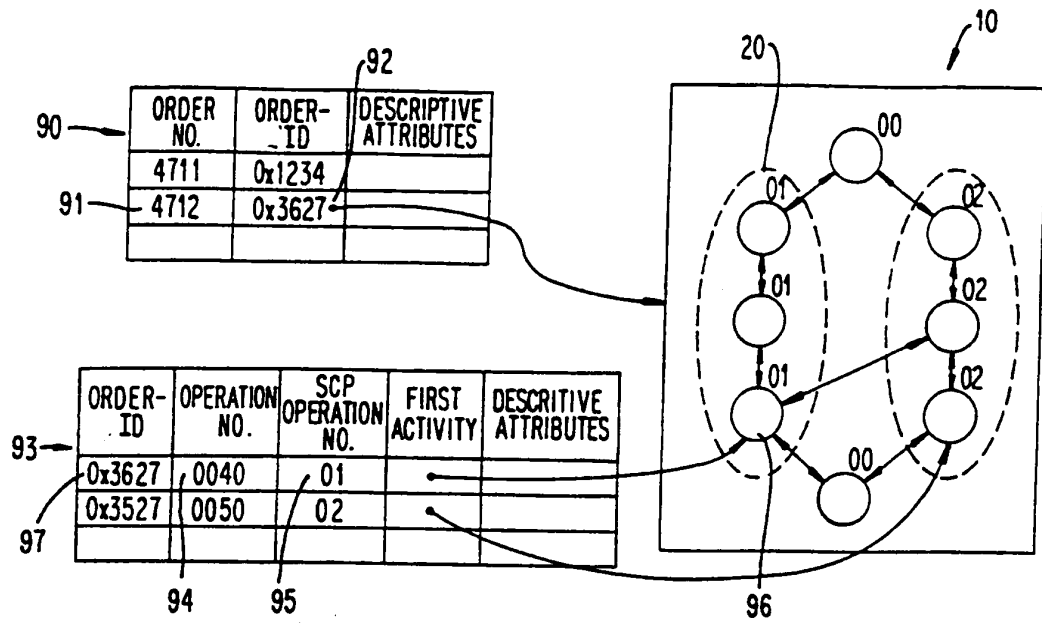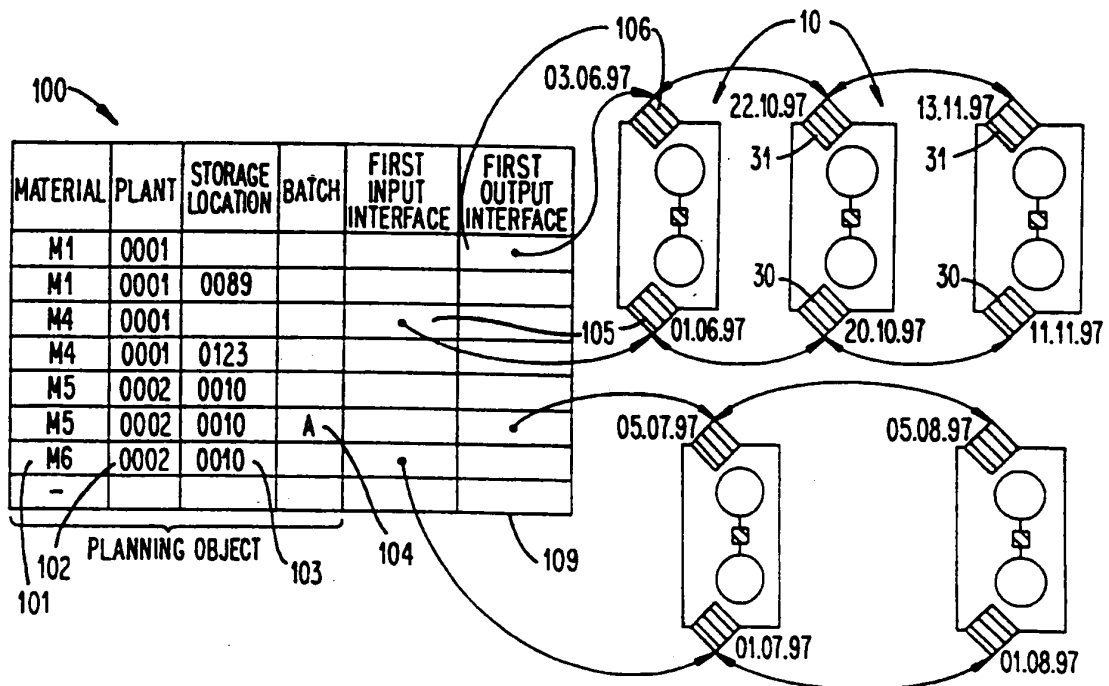
FIG_10

FIG. 11

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 303 144 A (KAWASHIMA KAZUHIRO ET AL) 12 April 1994 see column 1, line 45 - column 2, line 45 see column 4, line 12 - column 6, line 62 see column 8, line 33 - line 47 see column 10, line 55 - column 11, line 16 see figures 5,6,15A-B see figures 16A-B,19A-B	1,3-5,7, 8,10
Y	see figures 27A-B,28A-B --- -/--	2,6,9,10

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 July 1999	15/07/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl. Fax: (+31-70) 340-3016	Pedersen, N

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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